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Cross-Sectional Evaluation of Keratinized Gingiva Measurements Using Intraoral Scanning Versus Clinical Methods

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ABSTRACT

This research aimed to reexamine the interrelationship between gingival thickness (GT), keratinized gingiva width (KGW), papilla height (PH), and crown ratio (CR) using two assessment approaches: transgingival probing and an intraoral scanner (IOS). A total of 360 maxillary anterior teeth from 60 individuals were analyzed in this cross-sectional study. GT was recorded via transgingival probing with an endodontic spreader, while KGW, PH, and CR were measured digitally using an IOS. Statistical analyses involved one-way ANOVA, Student's t-test, and Spearman's rank correlation coefficients. The findings revealed a significant inverse association between GT and KGW in the central region (P=0.019). GT did not vary significantly among different teeth (P=0.06). Lateral teeth exhibited a lower PH (2.99 mm) compared to canines (P=0.047), whereas canines had a narrower KGW than central incisors (P=0.007). In the central area, a moderate positive correlation was observed between KGW and PH (P=0.01), while KGW and CR showed a weak negative relationship (P=0.043). In central teeth, GT and KGW, as well as PH and KGW, demonstrated moderate negative correlations, and a weak negative correlation existed between CR and KGW. The observation that KGW and GT were inversely related challenges the conventional assumption of a direct relationship between these parameters, with IOS-based measurement providing a refined perspective.

Keywords: Phenotype, Crown, Diagnosis, Dental papilla, Periodontics, Gingiva

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Introduction

Accurate evaluation of both the qualitative and quantitative characteristics of periodontal tissues plays a vital role in predicting the success of surgical and non-surgical periodontal interventions [1]. In previous literature, terms such as biotype, phenotype, and morphotype have been used interchangeably; however, the 2017 World Workshop on Periodontology standardized the term phenotype to replace biotype [2]. The periodontal phenotype not only affects therapeutic outcomes but also influences disease onset, progression, and the selection of appropriate treatment modalities [3,4]. Furthermore, a precise assessment of this phenotype is critical for achieving optimal esthetic and functional outcomes in implant placement, restorative dentistry, and periodontal surgical procedures [5, 6].

Two major determinants of the periodontal phenotype are gingival thickness (GT) and keratinized gingiva width (KGW) [2]. These parameters are closely associated with the presence of marginal inflammation, bleeding on probing, and gingival recession, emphasizing the importance of their accurate assessment prior to periodontal therapy [4]. GT, regarded as the principal indicator of gingival phenotype, exhibits a strong relationship with the likelihood of gingival recession [6–8]. It is typically categorized as thin when less than 1 mm and thick when exceeding 1 mm in thickness [9]. Research indicates that thicker gingiva (greater than 1 mm) is less prone to post-regenerative recession, and a GT of approximately 1.1 mm is considered a critical threshold for achieving complete root coverage in mucogingival surgeries [6, 9]. Thus, precise knowledge of GT is indispensable for treatment planning. Additionally, an adequate width of keratinized mucosa supports long-term periodontal stability and facilitates effective oral hygiene. When KGW measures below 2 mm, there is a greater tendency for plaque buildup and inflammatory changes [10].

In esthetically focused dentistry, particularly in the anterior region, the height of the gingival papilla (PH) and the crown ratio (CR) are key determinants of visual harmony [6, 11]. The apicocoronal dimension of the papilla, which plays a crucial role in preventing black triangle formation, requires detailed assessment [12]. Therefore, the clinical evaluation of PH, CR, GT, and KGW is foundational not only for periodontal management but also for orthodontic, prosthetic, and implant-based rehabilitations [3].

Various methods have been proposed for assessing the gingival phenotype, both qualitatively and quantitatively, including transgingival probing [8, 13], probe transparency assessment [6, 7], ultrasonography [7, 14], and intraoral scanning (IOS) [1, 15]. Among these, transgingival probing remains one of the most reliable and objective techniques since it provides direct quantitative measurements [7, 9]. The probe transparency method, in contrast, only distinguishes between thin and thick phenotypes without yielding precise numerical data [7, 9]. Direct measurement techniques employing endodontic files, periodontal probes, or acupuncture needles—collectively referred to as transgingival sounding or probing—are widely recognized as the gold standard for GT determination [3, 7, 8].

Similarly, KGW can be evaluated using periodontal probes or digital technologies such as IOS [15–17]. Evidence suggests that IOS offers greater reproducibility and accuracy compared to manual probing, which is subject to operator variability in probe positioning and angulation [15]. Based on this premise, the present study assessed KGW, PH, and CR using an intraoral scanner, while GT was measured via transgingival probing. Although prior investigations have explored associations between GT and related clinical parameters, inconsistent findings have been reported due to variations in methodology [11, 13, 16–21]. The advancement of digital dentistry has further enabled precise, reproducible assessments through digital imaging and high-resolution IOS technology, which has also been applied for KGW evaluation in recent literature [20].

Therefore, the objective of this study was to analyze the interrelationships among GT, KGW, PH, and CR utilizing an intraoral scanner. The null hypotheses tested were: (1) no significant correlations exist among GT, KGW, PH, and CR, and (2) these parameters do not differ significantly among the maxillary anterior teeth.

Materials and Methods

This cross-sectional investigation was carried out with prior authorization from the Akdeniz University Clinical Research Ethics Committee (approval number: 70904504/28). All volunteers were provided with detailed written and verbal information about the study, and participation proceeded only after signed consent was obtained. The study followed the ethical principles of the Declaration of Helsinki.

Study participants

To establish an adequate sample size, a power calculation was performed using G*Power 3.1 (Heinrich-Heine-Universität, Düsseldorf, Germany). Assuming an effect size of 1.50 [6], a 95% confidence level, and 95% statistical power, the minimum required sample size was estimated at 43 teeth per category. To strengthen the reliability of the analysis, 60 healthy individuals (30 males and 30 females; mean age 20.3 years, range 19–23 years) were recruited from patients attending the dental faculty clinic between April and May 2022 for routine examinations. Only native Turkish speakers were included to eliminate ethnic variations. In total, 360 maxillary anterior teeth were evaluated.

Participants were eligible if they exhibited good systemic health, had no gingival recession, were non-smokers, and were not taking any drugs known to influence gingival conditions (such as cyclosporine or phenytoin). All anterior maxillary teeth—including first premolars—had to be intact, free of caries, restorations, veneers, or crowns. Inclusion also required an Angle Class I molar relationship, normal overbite and overjet, and the absence of malocclusion, missing teeth, or previous orthodontic or periodontal interventions.

Individuals were excluded if they had systemic disorders, current or past use of medications associated with gingival enlargement, pregnancy, lactation, menstruation, gingival hyperplasia, or a history of orthodontic therapy. Further exclusion criteria included diastemas, loss of proximal contact, attrition scores exceeding 1 [22], or morphological irregularities in the maxillary anterior region. Subjects with calculus deposits, gingivitis, periodontitis, or bleeding on probing greater than 10% were also excluded [23].

During the initial clinical visit, plaque and gingival conditions were assessed using the Silness and Löe plaque index [24] and the Löe and Silness gingival index [25]. Probing depths were measured at six sites per tooth with a periodontal probe (Hu-Friedy, Chicago, IL, USA; 0.5 mm diameter) under light pressure (approximately 0.5 N). The gingival and plaque indices were expressed as percentages. Only individuals presenting with 0% plaque and gingival indices and probing depths below 3 mm [18] were included. Oral hygiene instructions and professional prophylaxis were performed when necessary before measurements began.

Intraoral scanning

To visualize the mucogingival junction, histochemical staining was used. The gingiva from the anterior region to the premolars was gently brushed with 5% iodine Lugol's solution using a cotton pellet until a distinct boundary appeared. The staining technique exploits the glycogen content difference—iodine binds to glycogen-rich alveolar mucosa but not to the keratinized gingiva, which contains minimal glycogen. Once the mucogingival line was clearly identified, a soft tissue retractor (Optragate, Ivoclar Vivadent®, Schaan, Liechtenstein) was positioned to prevent soft tissue movement during scanning.

Digital scans were obtained using the CEREC Omnicam system (Dentsply Sirona, Bensheim, Germany). The scanning protocol began at the occlusal and palatal surfaces of the right first premolar, progressed buccally, continued to the left side, and finally returned to the right quadrant [1]. Each scan captured the vestibular depth, mucogingival junction, and incisal edges of all anterior teeth, including first premolars. All scans were performed to a 20 mm depth, as recommended by the manufacturer.

Transgingival probing

Gingival thickness (GT) on the labial surface of the central, lateral, and canine teeth was determined using a transgingival sounding method with an ISO #30 endodontic finger spreader (Dentsply Maillefer, Ballaigues, Switzerland) fitted with a silicone stopper. A topical anesthetic spray containing 10% lidocaine (Xylocaine, AstraZeneca, Osaka, Japan) was applied before the procedure, while local infiltration anesthesia was avoided to prevent tissue swelling [26].

Measurements were taken along the mid-buccal aspect of each crown, 1 mm apical to the gingival margin [3]. The spreader was inserted perpendicularly until the underlying tooth surface was reached. Once the stopper's position was stabilized using a flowable composite resin (Clearfil Majesty ES Flow, Kuraray Noritake Dental, Tokyo, Japan), the material was cured with a light unit (Elipar DeepCure-S, 3M ESPE, Seefeld, Germany). After curing, the instrument was carefully withdrawn for measurement.

Two trained examiners—a periodontist with a decade of clinical experience (AMN) and an endodontist with five years of experience (DY)—performed all GT recordings. Calibration was achieved prior to data collection by independently measuring GT on six pilot participants (representing 10% of the total sample). The measurements were photographed and compared to ensure consistency. Inter-examiner reliability, assessed using Cohen's kappa, ranged from 0.88 to 0.94, reflecting excellent agreement. Both observers then assessed all anterior maxillary teeth using identical standardized methods.

GT measurement: Each depth of spreader insertion was photographed together with an endodontic ruler (Dentsply Sirona, Ballaigues, Switzerland). In total, 360 images corresponding to 360 teeth from 60 individuals were gathered to form the primary dataset. To assess observer consistency, two separate datasets (720 photographs) were generated for two examiners. The first set was assigned to observer AMN, and the second to observer DY. An independent examiner randomly labeled the photographs in both datasets to maintain objectivity. For calibration purposes, both observers measured 36 photographs (representing 10% of the total sample) to calculate Cohen's kappa values, which demonstrated high agreement (0.97–0.98). The two blinded investigators (AMN and DY) then performed GT evaluations using ImageJ software (National Institutes of Health, Bethesda, MD, USA) twice, with a two-week interval between sessions. Each session included measurements of 10 images at a time, with rest periods between sets to minimize visual fatigue. Inter-class and intra-class correlation coefficients (ICCs) were subsequently determined for both observers based on the two measurement sessions.

Measurement of KGW, PH, and CR: An intraoral scanner (CEREC Omnicam, software version 4.6.1, Dentsply Sirona) was employed for these evaluations, utilizing 3D digital models for all measurements. During data collection, each tooth was centered on the display to clearly show its mesial and distal boundaries and the entire buccal surface **(Figure 1)**. The same two calibrated investigators (AMN and DY), trained on the data of six subjects (10 percent of the overall sample), performed the assessments. Their reliability was confirmed by Cohen's kappa values ranging from 0.94 to 0.97. One examiner conducted three separate measurements for every sample, and the mean of these readings, expressed in millimeters, was used for subsequent statistical analysis.

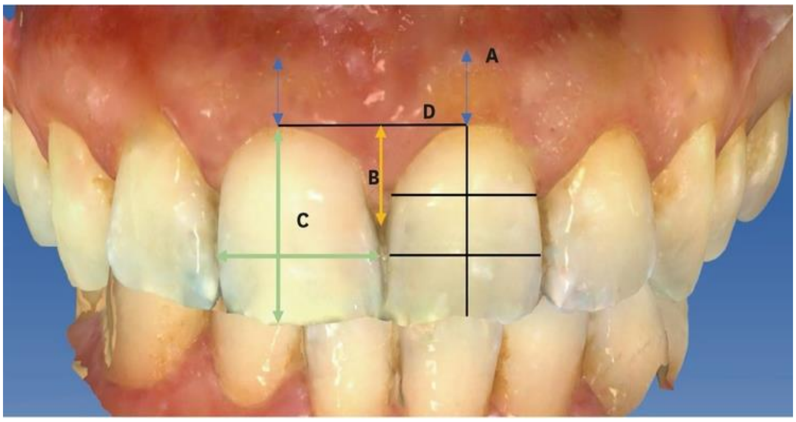

Figure 1. Illustration of measurement procedures for keratinized gingiva width (A), papilla height (B), and crown dimensions (C) in central teeth, with the connecting line between gingival zenith points of neighboring teeth shown in (D)

Keratinized Gingiva Width (KGW): The most apical points of the gingival margins (zeniths) of two adjacent teeth were identified and joined to form a zenith line [5]. From this reference, the perpendicular distance to the crown's central vertical axis was measured. The linear distance extending from the mucogingival junction to the gingival margin defined the KGW.

Papilla Height (PH): The papilla height was determined by measuring the linear distance from the zenith line to the papillary tip, aligned with the tooth's long axis.

Crown Ratio (CR): Both crown length and width were measured to calculate the ratio. Crown length was taken from the gingival zenith point to the incisal edge, perpendicular to the zenith line. For crown width, the total crown length was divided equally into coronal, middle, and incisal thirds, and the width was taken at the junction between the coronal and middle portions, parallel to the zenith line [6]. The CR value was obtained by dividing the width by the length of the crown.

To verify consistency, both observers repeated measurements for PH, CR, and KGW twice to evaluate intra- and inter-observer agreement.

Statistical analysis

All analyses were conducted using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was applied to examine normality. Because the data were not normally distributed, the Spearman correlation test was used to analyze relationships among GT, KGW, PH, and CR. Differences in GT and KGW among teeth were tested with one-way ANOVA, and sex-based comparisons were evaluated using the Student's t-test. The threshold for statistical significance was $P<0.05$ (95% CI). Reliability between and within observers was assessed using intra-class correlation coefficients (ICCs) with a significance level of $P<0.001$.

Results and Discussion

Eighty-one individuals were initially assessed, but only 60 satisfied the inclusion criteria, contributing a total of 360 anterior maxillary teeth. Throughout the procedures and the two-day follow-up, no postoperative complications such as bleeding, infection, soft tissue injury, or petechiae were recorded.

Table 1 presents the mean and standard deviation values of GT, KGW, PH, and CR for the maxillary anterior teeth. According to the one-way ANOVA, GT showed no significant variation among the teeth (P=0.06). In contrast, KGW was significantly different between central incisors and canines (P=0.007), and PH differed significantly between canines and lateral incisors (P=0.047). CR values peaked in the central incisors and were lowest in the lateral incisors (P<0.001). None of the measured parameters showed statistically significant differences between male and female participants (P>0.05).

Table 1. Values of GT, KGW, PH, and CR in central, lateral, and canine teeth (in mm)

Variables	Central (n=120)	Lateral (n=120)	Canine (n=120)	*P* value
GT	1.01±0.02	1.00±0.02	0.96±0.02	0.06
KGW	4.80±0.13[a)]	4.67±0.12	4.23±0.13[a)]	0.007[a)]
PH	3.20±0.11	2.99±0.06[a)]	3.24±0.07[a)]	0.047[a)]
CR	0.88±0.01[a)]	0.79±0.01[a)]	0.80±0.01[a)]	<0.001[a)]

Data are expressed as mean ± standard deviation.
Abbreviations: GT, gingival thickness; KGW, keratinized gingiva width; PH, papilla height; CR, crown ratio.
[a]) Indicates statistically significant differences based on one-way analysis of variance (P<0.05).

Table 2 and **Figure 2** illustrate the associations among the evaluated parameters. In the central region, gingival thickness (GT) and keratinized gingiva width (KGW) were moderately inversely related (P=0.019). Likewise, KGW showed a moderate negative association with papilla height (PH) in the same region (P=0.01). A weak inverse relationship was also observed between KGW and crown ratio (CR) in central teeth (P=0.043). No significant correlations were detected for any of these parameters in the lateral and canine regions (P>0.05).

Table 2. Correlations between GT, KGW, PH, and CR in central, lateral, and canine teeth

Variables	GT (r-value)			KGW (r-value)			PH (r-value)		
	Central	Lateral	Canine	Central	Lateral	Canine	Central	Lateral	Canine
CR	0.107	−0.053	0.201	−0.264[b)]	−0.119	−0.088	0.083	−0.001	−0.040
PH	0.085	0.019	−0.193	−0.333[c)]	0.085	−0.024	1.000	1.000	1.000
KGW	−0.305[a)]	−0.158	−0.071	1.000	1.000	1.000	−0.333[c)]	−0.085	−0.024

Abbreviations: GT, gingival thickness; KGW, keratinized gingiva width; PH, papilla height; CR, crown ratio.
Superscript lowercase letters indicate statistically significant correlations based on the Spearman test: [a]) P=0.019, [b]) P=0.043, [c]) P=0.010.

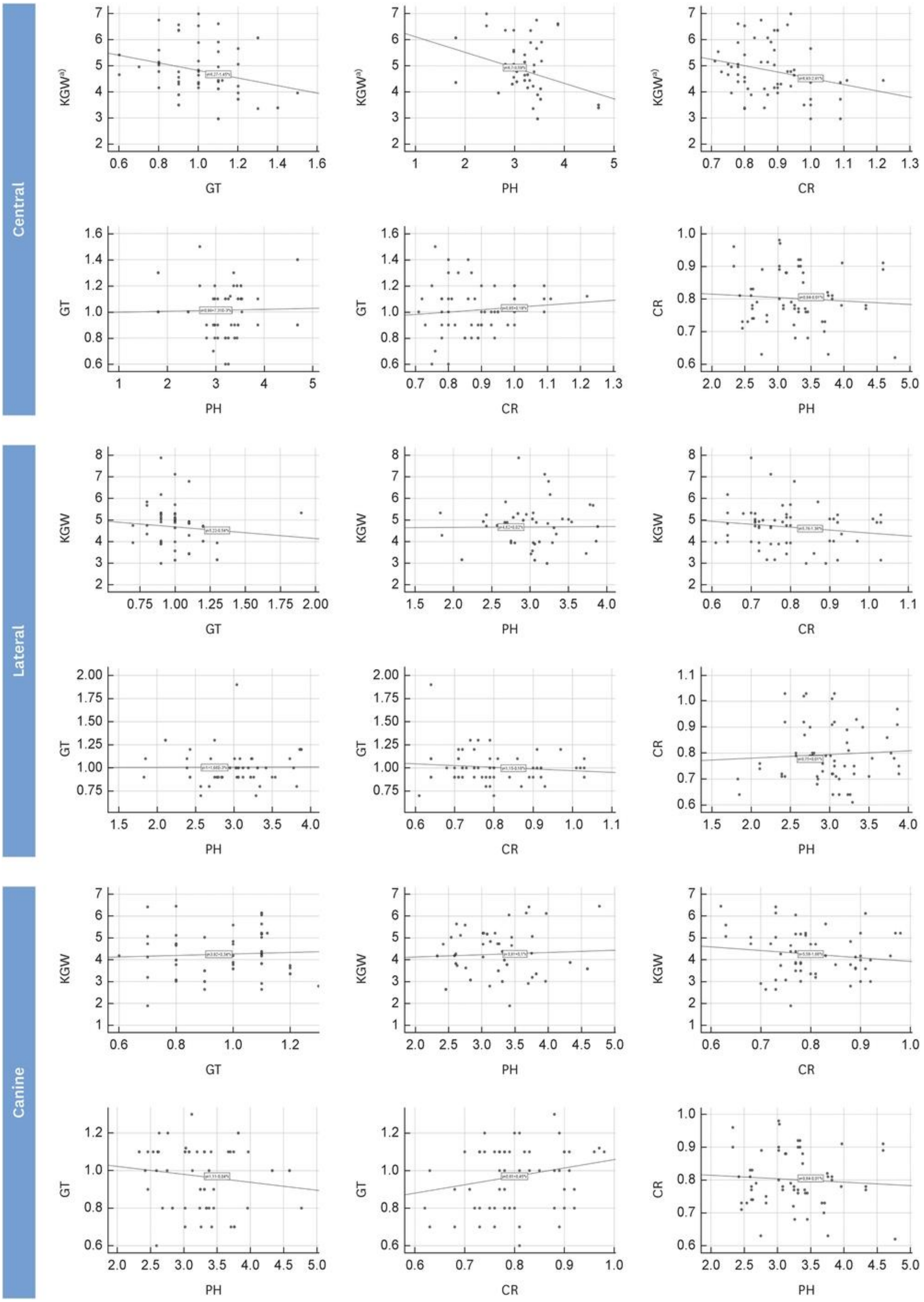

Figure 2. Scatter plots illustrating the relationships among GT, KGW, PH, and CR for central, lateral, and canine teeth.

Abbreviations: GT, gingival thickness; KGW, keratinized gingiva width; PH, papilla height; CR, crown ratio.

[a]) Indicates statistically significant correlations according to the Spearman test (P<0.05).

For the first dataset, the ICCs for GT measurements were 0.974 and 0.982, while for the second dataset they were 0.979 and 0.991. No significant differences were observed between measurements from the two datasets (P>0.001). Similarly, intra- and inter-observer values for KGW, PH, and CR showed no significant differences (P>0.001).

The main outcome of this study revealed a weak negative correlation between GT and KGW, as well as between KGW and PH and CR, specifically in the central incisors. No significant correlations were observed in lateral incisors or canines, nor among other parameters across all maxillary anterior teeth, partially rejecting our first null hypothesis.

Periodontal phenotype plays a critical role in post-treatment healing, emphasizing the need for precise measurement methods rather than subjective approaches that can produce inconsistent findings [23, 27]. The second null hypothesis was partially refuted, as no differences were detected in GT across anterior teeth, but variations were present for KGW, PH, and CR.

In this study, GT ranged from 0.96 to 1.01 mm, consistent with prior reports of 0.81–1.23 mm [28, 29]. Achieving full root coverage generally requires a minimum GT of 1.1 mm [30], suggesting that maxillary anterior teeth in our sample may be more likely to require secondary periodontal surgery for root coverage. Although GT has been proposed as either site-specific or patient-specific [11], we found no significant differences among anterior teeth, in contrast to some previous studies indicating canines as having the thinnest gingiva [16, 17]. Conflicting evidence exists regarding sex-based differences in gingival phenotype [16, 23, 31, 32]; in this study, no differences were observed between male and female participants, aligning with some reports [16, 23] but not others [31, 32].

GT was measured using an endodontic spreader, though other studies have employed endodontic files [21], needles [7], or periodontal probes [7, 11, 16]. The spreader is particularly suitable for precise measurements, avoiding the friction and micro-retention issues that can arise with bladed instruments such as files.

Measurements were recorded in millimeters rather than using categorical classifications like thin or thick biotype, enabling detection of subtle variations in gingival thickness. The conventional 1-mm threshold for categorizing gingiva may be insufficiently precise for diagnosis and prognosis [3], making quantitative data more reliable and potentially informative for future re-evaluation of clinical criteria. Limitations of transgingival probing include its invasive nature and reduced sensitivity in very thin tissues [21].

Non-invasive intraoral scanners (IOS) have increasingly been explored for periodontal tissue assessment [8, 15, 33], extending beyond simple digital measurements to tracking gingival morphological changes after initial periodontal therapy [34]. In this study, we compared gingival thickness (GT) with keratinized gingiva width (KGW) measured using IOS, a method previously validated for periodontal evaluation [7]. Clinically, this approach highlights the advantage of assessing KGW through a straightforward, non-invasive technique that is generally more reliable than traditional probing [15] when considered alongside GT.

Our findings showed that all maxillary anterior teeth exhibited KGW values above 2 mm, in line with previous research [11, 16, 21, 33, 35, 36]. Canines displayed narrower KGW than central incisors, although the literature reports inconsistent results, with some studies indicating higher KGW in central incisors [35], others in canines [13, 31, 35], or no notable difference between the two [17, 19, 21].

Accurate identification of the mucogingival junction is essential for precise KGW measurement, as it demarcates the boundary between movable and attached mucosa. Studies have shown no significant differences between visual assessment (scalloped line detection), functional assessment (sliding a horizontally positioned probe to assess mobility), and histochemical staining using iodine [37]. More recently, digital software approaches have been applied to isolate oral mucosa for junction identification [20]. In our study, we employed histochemical staining to define the junction.

KGW–GT relationship: Traditionally, KGW is measured using periodontal probes due to simplicity [11, 16, 19]; however, these can overestimate width by about 1 mm [15]. Using IOS, we observed a negative correlation in the central teeth: thinner gingiva corresponded to wider KGW.

Most previous studies report a positive relationship between GT and KGW [11, 13, 16, 17, 19, 21, 36], although some found no correlation [6, 38]. Differences may arise from variations in methodology or ethnic factors. Since many prior studies relied on periodontal probing, their KGW values may be overestimated [15], suggesting a need to revisit these findings. Methodological heterogeneity in the literature has also been highlighted in recent reviews [4], and high-resolution photographs have been used to measure KGW in some studies [20]. Clinically, when a tooth exhibits a wider KGW, careful evaluation of GT, especially in central incisors, is recommended.

While IOS offers a non-invasive means of assessing KGW, our GT measurement was invasive. Non-invasive alternatives, such as superimposing CBCT scans with IOS data, have produced GT values comparable to direct probing [39], offering a radiation-conscious option when CBCT images are available.

Papilla height (PH) in this study ranged from 2.99 to 3.24 mm, with lateral incisors showing lower PH than canines. Various reference lines have been used in prior studies to measure PH, such as connecting the zenith points of adjacent teeth [6, 12, 23, 27, 40] or using a line perpendicular to the tooth's long axis from the gingival zenith [13, 41- 43]. Reported PH values for maxillary anterior teeth range from 3.26 to 5.16 mm [5, 6, 11-13, 23, 27, 36, 38, 40- 43], making our measured 2.99 mm the lowest value reported in healthy subjects.

Previous measurements relied on periodontal probes [5, 11, 36, 38, 41] or calipers on casts [6, 12, 13, 23, 43], both of which assess curved surfaces with linear instruments and often neglect three-dimensional angles, reducing repeatability. Like KGW, probe-based methods may overestimate PH [15]. Standardized jigs can improve measurement reliability by controlling probe position and angle. Scans from cast models, as used by Yin *et al.* [27], may be influenced by impression and modeling errors, whereas our direct digital scanning of the papilla allowed for more accurate in vivo measurements, likely explaining discrepancies with previous reports.

Relationship between PH and GT: Our analysis did not show any connection between papilla height (PH) and gingival thickness (GT) in the maxillary anterior teeth. Previous research presents conflicting evidence: some studies found no link [36], whereas others suggested higher papillae occur with either thick [11] or thin gingival biotypes [41, 43]. Notably, these studies relied on qualitative assessments rather than numerical data [11, 41, 43], while our study applied precise quantitative measurements to explore this relationship.

Relationship between PH and KGW: We identified a moderate inverse relationship between keratinized gingival width (KGW) and PH. Earlier investigations did not demonstrate a significant correlation [11], likely because KGW was assessed using a periodontal probe without reporting exact measurements. In contrast, our quantitative evaluation revealed that larger KGW values were associated with lower papillae. More studies using reliable, accurate tools are needed to clarify this association further.

Crown Ratio (CR) Observations: In the present study, the central incisors exhibited higher CR values compared with canines and lateral incisors, consistent with previous findings [12, 23]. Literature shows diverse methods for CR assessment, such as measuring crown width at apical and middle thirds [6, 12, 13, 40] or at the incisal third [12, 23]. While both approaches provide useful information, apical width reflects the emergence profile, and incisal width relates to the contact area. Some studies suggest that cervical width may offer a more objective measurement, yet dividing the crown into three segments allows either cervical or incisal widths to yield reliable results.

Relationship between CR and GT: No association between CR and GT was observed in our dataset, supporting the findings of certain previous studies [13, 35]. However, some reports have indicated a positive correlation [22, 36, 40].

Relationship between CR and KGW: We found no link between CR and KGW. Only limited research has addressed the relationship between attached gingiva and crown length, showing mixed results [13, 31, 40]. Positive correlations in previous studies were often attributed to attrition or gingival recession [13], but our study excluded such cases.

Relationship between CR and PH: Our results did not reveal a correlation between CR and PH. While several studies suggest that papilla morphology is influenced by crown form [6, 12, 13, 23, 40], and that longer crowns are typically associated with taller papillae [12, 13, 23], differences in methodology or study populations may explain discrepancies. Factors such as crown wear could have affected prior results in older cohorts. Moreover, crown shape matters; square-shaped crowns are thought to have longer contact points and shorter papillae [6, 12, 23]. Unlike these studies, our analysis did not detect a relationship between crown shape and papilla height. Previous methods often used periodontal probes, with measurements rounded to 0.5 mm [6], or digital calipers on casts [5, 12, 23]. Our study leveraged intraoral scanning (IOS) for precise digital measurements, ensuring repeatable and highly accurate data. Studies using photographs with ruler guidance [40] reported some relationships between crown form and PH, but IOS provides more reliable results. Future work should compare the accuracy of various digital measurement techniques.

Limitations: This study excluded certain age ranges and relied on a single IOS system. Findings are specific to maxillary anterior teeth in the native Turkish population. While mean values offer a reference, clinical assessments must be individualized. A strength of this research is the use of IOS, which allows reproducible and accurate measurement of KGW in relation to GT and other parameters. Key findings include the negative correlation between GT and KGW, highlighting the enhanced precision of IOS compared with traditional periodontal probing, and the need for further validation studies.

Conclusions

- KGW and GT in the central region demonstrated a moderate inverse relationship using IOS measurements.
- The commonly assumed positive correlation between GT and KGW may not hold.
- PH showed a moderate negative association with KGW in the central region.
- A weak negative correlation was observed between CR and KGW centrally.
- PH values were lower in lateral incisors compared with canines, while KGW was narrower in canines than in central incisors.

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Ethics statement: None

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